CPT/CPTU – Course

Covered in day 1:

-Introduction on CPT/CPTU

-Stratigraphy/soil classification

-Soil parameters in clay

-Other sensors for geotechnical purposes

-CPT technology for environmental applications

CPT/CPTU – Course

Covered in day 1:

-Introduction on CPT/CPTU

-Stratigraphy/soil classification

-Soil parameters in clay

-Other sensors for geotechnical purposes

-CPT technology for environmental applications

Suggest to cover in day 2:

-Historic overview/CPT/CPTU in todays practice/equipment and procedures/deployment procedures/data processing/standards and specifications

-Soil parameters in sand

-Direct application of CPT results: SPT/CPT correlations, pile bearing capacity, compaction control etc

-Case histories (Don/Lorraine/Tom)

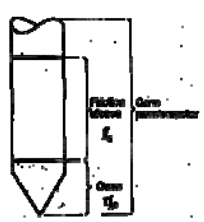
-Participants contributions/questions

-Examples of unusual behaviour/examples other soil types

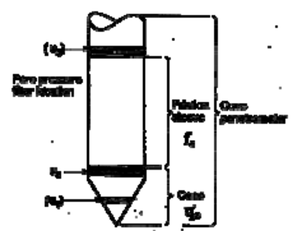
CPT/CPTU – equipment/procedures/standards etc

- **What is a CPT/CPTU and what do we measure ?**
- **Equipment for testing:**
  - ***Deployment***
  - ***Cone penetrometers***
  - ***Data aquisition***
- **Procedures**
- **Processsing and presentation of results**
- **Available standards and guidelines**
- **Corrections**

TERMINOLOGY FOR CPT

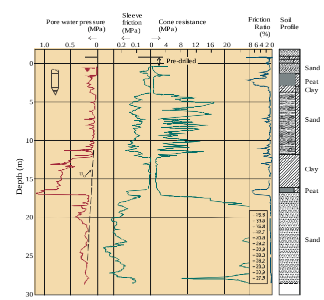


TERMINOLOGY FOR CPTU AND WHAT DO WE MEASURE



In addition frequently measure inclination, i

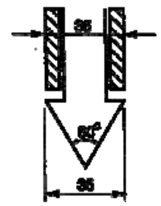
Example CPTU profile from Holland



HISTORICAL BACKGROUND CPT

- 1932 First Dutch cone penetration tests (by hand)
- 1935 Delft Soil Mechanics Laboratory (DSML) performs CPT with 10 t manually operated rig
- 1948 Improved design of Dutch cone including conical mantle
- 1953 Measurement of friction sleeve added to mechanical cone
- 1948 DSML develops first electrical cone
- 1965 Fugro develops electrical friction cone
- 1974 Janbu and Senneset (Norway) and Schmertmann (USA) penetrates conventional piezometer. Wissa et al. (USA) and Torstensson (Sweden) simultaneously piezoprobe
- 1980 Roy et al. (Canada) develops probe with combined measurement of cone resistance, sleeve friction and pore pressure

OLD TYPE DUTCH CONE (FROM SANGLERAT, 1972)

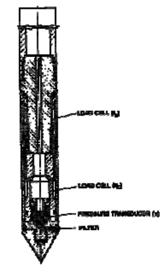


Dutch cone penetrometer system
used in the 1940s
(courtesy of Delft Geotechnics)

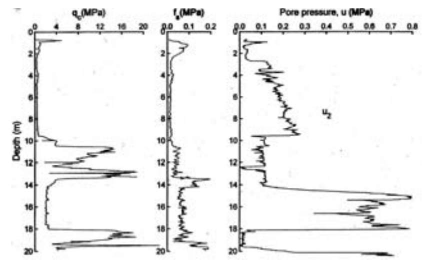
CPT/CPTU on land

Modern truck mounted system *(ConeTec/Gregg)*

Example combined CPT and pore pressure probe Piezocone or CPTU



Examples measured CPTU parameters



Example: Measured CPTU Parameters

ROLE OF CPT/CPTU IN TODAYS SOIL INVESTIGATIONS

Onshore Scandinavia

- Used in large projects by knownledgeable clients
- Gradually taking over after the vane tests; results used for soil profiling and also to define parameters for foundation design
- However, the full potential is not yet used. Not all clients and consultants are aware of the advantages of the test

ROLE OF CPT/CPTU IN TODAYS SOIL INVESTIGATIONS

Offshore North Sea

- Since 1972 has dominated offshore soil investigations (> 50%)
- Used in most projects
- In some cases investigation consists of only CPTUs

Deployment of CPT/CPTU

Equipment now exists for pushing in cone penetrometers into soil for a large range of conditions
- on land
- offshore

'Old' mechanical CPT rig still in use in Indonesia

Bandung University, Indonesia, 2000

Example CPT rigs

Geomil rig

Geotech simple rig

CPT/CPTU on land

Track-mounted system

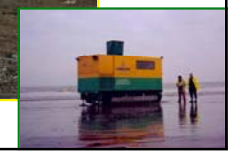
(ConeTec/Gregg)

Coson® 200 kN

- Continuous Static cone penetrometer
- Take-over principle
- Time saving about 7 sec/m
- No loss of data at one meter intervals
- No dissipation effects interfering with pore water pressure measurements.

Standard CPT Rigs

20 Tonne Crawler



Non-Standard CPT Rigs

15 Tonne Rail Crawler

- Rapid investigative technique. Minimal set-up and test time per loca
  No reinstatement required
- Optimises track possession time more effectively
- Mini-crawler with inclined rams for rail embankments
- No lifting required for mobilisation

Non-Standard CPT Rigs

1.5 Tonne Mini Crawler

- **Suitable for restricted access (rubber tracked, low ground bearing pressure)**
- **Thrust capacity 20 tonnes**
- **Reaction weight 1.5 tonnes (increased with ground anchors & water tanks)**
- **Suitable for Railway related work**

Pagani small trackmounted CPT rig

Onsøy, Norway, March 2001

Versatile Mobile Rams

LANKELMA

Embankment CPT's

CPT/CPTU on land

Drill-rig system

(ConeTec)

Low headroom CPT - Inside buildings

(ConeTec/Gregg)

CPT in London Underground tunnel

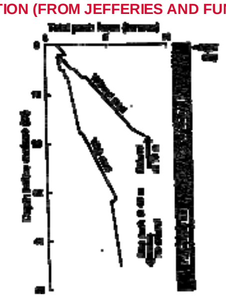
Courtesy of Lankelma, UK

CPT/CPTU

Increasing penetration:

- Increase pushing force
- Reduce rod friction
- Carry out test in drilled borehole

TOTAL CONE PUSH FORCES WITH AND WITHOUT MUD INJECTION (FROM JEFFERIES AND FUNEGÅRD, 1983)



In situ testing in offshore geotechnical investigations

Deployment platforms

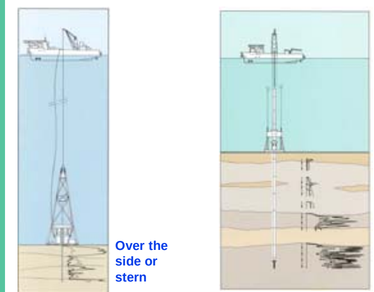
- Jack up rigs
- Barges
- Survey ships
- Special soil drilling vessels

NGI

Investigations from jack-up platform

NGI

Deployment from vessels



From Fugro brochure

NGI

In situ testing in offshore geotechnical investigations

Basically two modes of operation:

- Seabed mode
- Down-hole mode

NGI

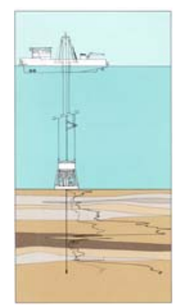
In situ testing in offshore geotechnical investigations

Sea bottom rigs:

- Standard size rigs (e.g. 10 or 15 cm^2 cone penetrometers)
- Minirigs (1 to 5 cm^2 cone penetrometers)

NGI

Fugro's wheeldrive CPT system



Heavy duty rig 20 t, profiling to 45-50 m penetration possible

From brochure

NGI

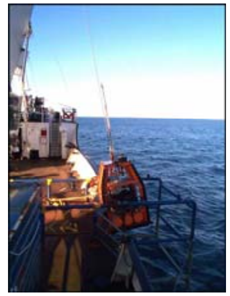
Roson rig with one set of roller wheels

5 ton rig for pipeline investigations with standard size cones

From AP van den Berg brochure

NGI

CPT rig with acoustic telemetry



Light version:

-weight < 3 tons

-thrust capacity 1 ton

-base area 2.25 m^2

-2 cm^2 - 5 cm^2 cones

From Gardline brochure

NGI

Example of light mini-rig for use in deep waters

Global, UK

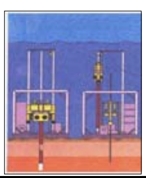
NGI

Geo's combined CPT and Vibrocore seabed rig "GeoCeptor"

•CPT and vibrocore in "one operation"

• CPT up to 10 m depth

• Soil sampling up to 6 m depth



NGI

GEO "CPT-ROV"

Weight: 200kg

Deployment depth: 3000m

Max penetration: 3 m

Cone dimensions:

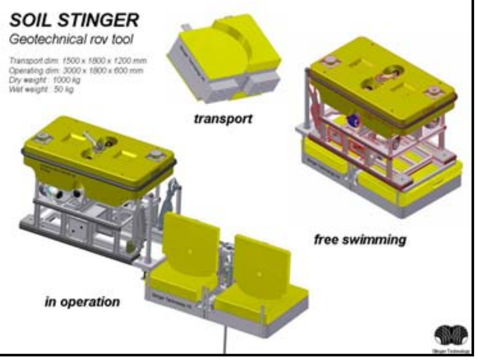
10cm^2 5cm^2

NGI

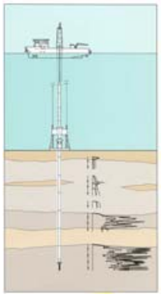
Soil stinger

New Norwegian system that can potentially be used for shallow tests deployed from ROV

NGI



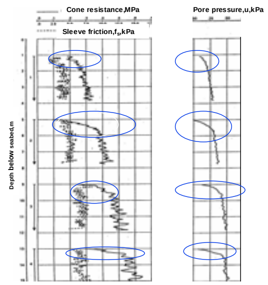
Down-hole insitu testing



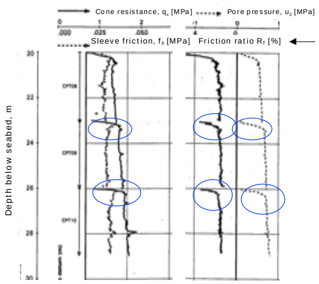
Operation with umbilical, hydraulic cylinder pushes tool below bottom of borehole. Data aquisition through cable and real time display of test results. Depth limitation about 700 m.

From Fugro brochure

Example of downhole CPT showing soil disturbance due to drilling



Example of downhole CPTU showing little drilling disturbance



Seabed or down-hole testing ?

Advantages of down-hole testing:

- Penetrations to 150 m or more
- Hard layers can be penetrated
- Possible to do combination of different types of in situ tests and/or sampling

Seabed or down-hole testing ?

Advantages of seabed testing:

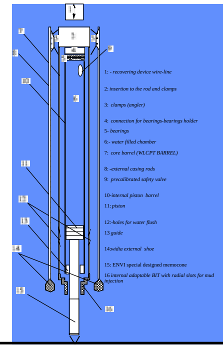
- Easier and quicker deployment
- Less expensive ships can be used
- Higher quality of tests due to no soil disturbance due to drilling

New alternative CPTU while drilling

Developed by Italian company SPG and Swedish company ENVI

- Cone penetrometer protrudes in front of drill bit while drilling in same way as a corer
- CPTU data stored in a memory unit
- Drilling parameters logged at same time

CPTU while drilling; principle



(From M.Sachetto,2001)

DETAIL OF MEMOCONE AND THE CPTwd-BARREL BIT

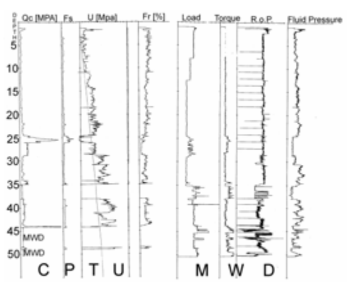
SLOTS FOR THE MUD INJECTION

ENVI MEMOCONE

CPTwd-BARREL BIT (rotating part)

From M.Sachetto,2001

Result from CPTU while drilling

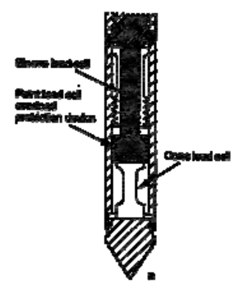


From Sachetto(2001)

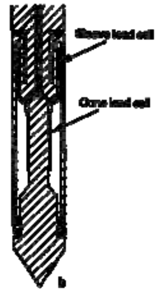
CPT/CPTU MEASUREMENT SYSTEM

- Cone resistance/sleeve friction strain gauge load cells
- Pore pressure - pressure sensors
- Data acquisition
  - *Transmission via cable*
  - *Wireless transmission*
  - *Storing data in memory mode*

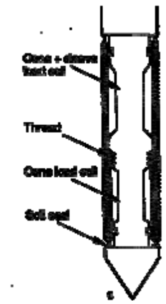
DESIGN OF CONE PENETROMETERS. (a) CONE RESISTANCE AND SLEEVE FRICTION LOAD CELLS IN COMPRESSION



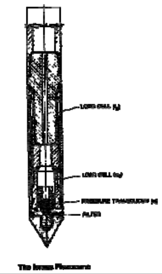
DESIGN OG CONE PENETROMETERS. (b) CONE RESISTANCE LOAD CELL IN COMPRESSION AND SLEEVE FRICTION LOAD CELL IN TENSION



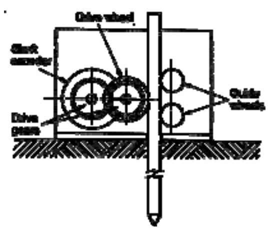
DESIGN OF CONE PENETROMETERS. (c) SUBSTRACTION TYPE CONE PENETROMETER.



Typical piezocone with two separate load cells for cone resistance and sleeve friction and a pressure transducer for pore pressure measurements



EXAMPLE OF DEPTH REGISTRATION SYSTEM



EXAMPLE OF DEPTH REGISTRATION SYSTEM

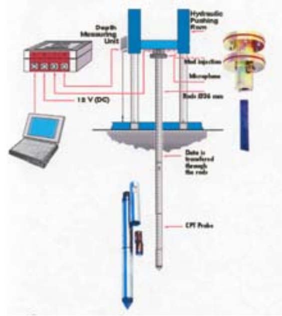
Courtesy of APvandenBerg

CPT/CPTU MEASUREMENT SYSTEM

- Cone resistance/sleeve friction strain gauge load cells
- Pore pressure - pressure sensors
- Data acquisition
  - *Transmission via cable*
  - *Acoustic transmission*
  - *Storing data in memory mode*

CPT/CPTU MEASUREMENT SYSTEM

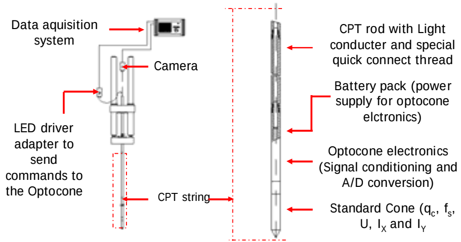
GEOTECH'S SYSTEM WITH ACOUSTIC TRANSMISSION OF SIGNALS



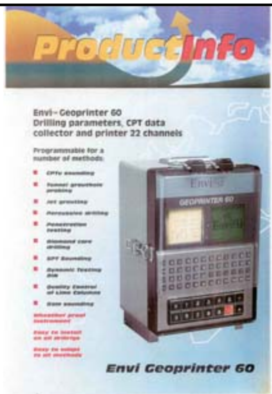
From Geotech brochure

GEOTECH'S SYSTEM WITH ACOUSTIC TRANSMISSION OF SIGNALS

Schematic overview Optocone® System



From ENVI brochure



CPT/CPTU AVAILABLE STANDARDS AND GUIDELINES

- International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE): IRTP (International Reference Test Procedure) 1999
- ASTM D: 5778-95, 2000
- BS: 1377, Part 9, 1990
- Dutch Standard, NEN 5140, 1996
- Norwegian Geotechnical Society Guidelines (1995)
- Eurocode, ISO/FDIS 22476-1:2006(E).13 (2007)
- And other National Standards/codes

ASTM D 5778 (1995/2000)

Designation: D 5778 – 95

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
Reprinted from the Annual Book of ASTM Standards. Copyright ASTM

Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils[1]

Coming European Standard

CEN/TC 341/WG2
Date: 2006-04
ISO/FDIS 22476-1.10

Ground investigation and testing — Field testing
— Part 1: Electrical cone and piezocone penetration tests (CPT and CPTU)
— Part 15: Mechanical cone penetration test (CPT)

Present stage : CEN Enquiry

Plan to be valid: about 2007

Untill then IRTP(1999) is the official international document

Main elements of new Eurocode on CPT/CPTU ISO/FDIS 22476-(E).13

- Equipment
- Procedures
- Corrections
- Other aspects

See also IRTP (1999)

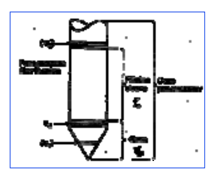
Main elements of new Eurocode on CPT/CPTU ISO/FDIS 22476-(E).13

Equipment:
- Cone apex angle : 60 degr.
- Diameter : 36 mm (opens up for range : 25 to 50 mm)
- Area friction sleeve 150 sq.cm
- Prefered filter location for CPTU behind cone

Procedures

Corrections

Other aspects



Pore Pressure

- The pore pressure, u, is the fluid pressure measured during penetration and dissipation testing. The pore pressure can be measured at several locations as shown in Figure 2.3.
- The following notation is used:
- u_1: Pore pressure measured on the cone face
- u_2: Pore pressure measured at the cylindrical extension of the cone
- u_3: Pore pressure measured immediately behind the friction sleeve

Filter location

Theoretical studies and practical experience have shown that the measured pore pressure varies with the soil type and also the location of the filter element.

NGI

Example of effect of pore pressure location on measured pore pressure

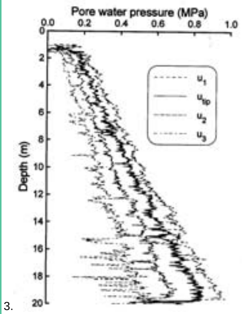
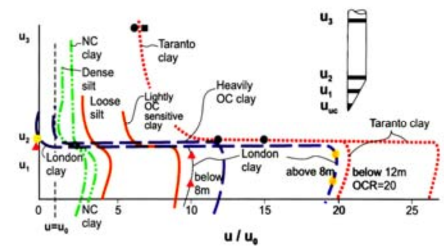


Fig 3.

Bothkennar, UK soft clay

NGI

Measured pore pressure distributions



NGI

Filter location

The new European Standard (and also IRTP (1999)) refers to the location behind the cone (u_2) as the recommended filter location. The advantages of this filter location can be summarised as:

- The filter is much less prone to damage and wear
- Measurements are less influenced by element compressibility
- Pore pressures measured can be used directly to correct cone resistance .
- Measured pore pressures during a dissipation test are less influenced by procedure (locking rods or not)

NGI

Main elements of new Eurocode on CPT/CPTU ISO/FDIS 22476-(E).13

Equipment

Procedures:

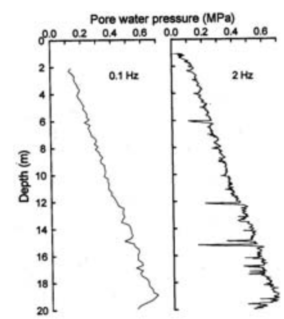
- Penetration speed : 2 cm/sec
- Log at least one set of readings every sec (2.0 cm)
- Requirements to saturation of pore pressure measurement system
- Dissipation tests: stop penetration and log u vs time

Corrections

Other aspects

NGI

Effects of frequency of readings on pore water pressure profile

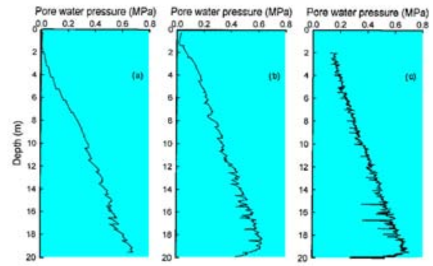


NGI

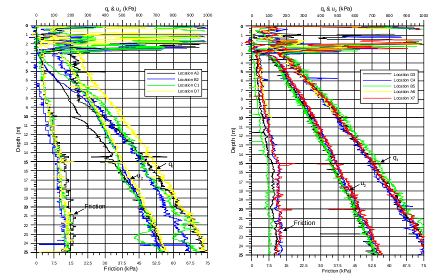
Field saturation of piezocone

Onsøy, Norway 2001

Importance of saturation on measured pore pressure response



CPTUs at NGI's Onsøy site



Example of test series with bad saturation

Example of test series with satisfactory sturation

Filter saturation

- Misleading results will be obtained if the filter and its measuring system is not fully saturated.
- Errors will then also occur in the calculation of q_t

Example of dissipation test

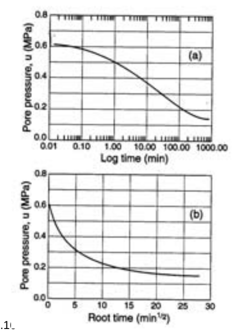


Fig 3.1

Required logging frequency according to ISO/FDIS 22476-(E).13

-1st minute at least: 1 Hz

-Thereafter may half every log (time) cycle

Main elements of new Eurocode on CPT/CPTU ISO/FDIS 22476-(E).13

Equipment

Procedures

Corrections:

- Pore pressure effects on cone resistance
- Effect of inclination

Other aspects

Pore water pressure effects on q_c and f_s

- Due to the "inner" geometry of a cone penetrometer the ambient pore water pressure will act on the shoulder area behind the cone and on the ends of the friction sleeve.
- This effect is often referred to as "the unequal area effect" and influences the total stress determined from the cone and friction sleeve.
- For the cone resistance the unequal area is represented by the cone area ratio 'a' which is approximately equal to the ratio of the cross-sectional area of the load cell or shaft, A_n, divided by the projected area of the cone A_c .

Piezocone Testing in Clay

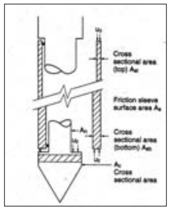
Correction for pore pressure effects on cone resistance:

$q_t = q_c + (1-a)u_2$

q_c= measured cone resistance

a = area ratio (0.3- 0.85)

u_2= measured pore pressure behind cone



Simple chamber for calibration of a and b factors

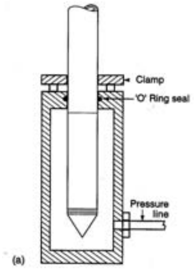


Fig 2.18a

Determination of area ratio, a, in calibration vessel

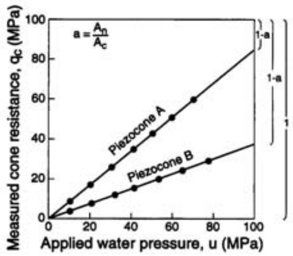
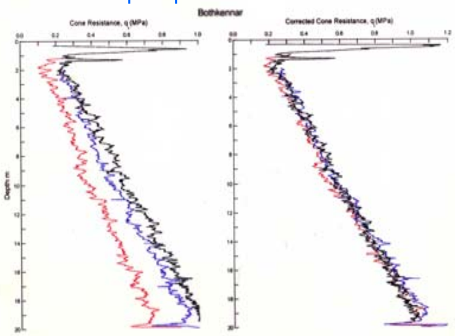


Fig 3.2

Effect of pore pressure on cone resistance



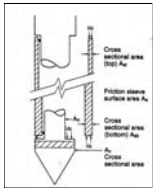
Cones with area ratio a = 0.59 to 0.9

Pore water pressure effects on f_s

When excess pore pressures are generated the pore pressures are normally different at the upper (u_3) and lower (u_2) ends of the sleeve.

The corrected sleeve friction, f_t, can be given by:

$$f_t = f_s - (u_2 . A_{sb} - u_3 . A_{st}) / A_s$$



Example of correcting f_s for pore pressure effects

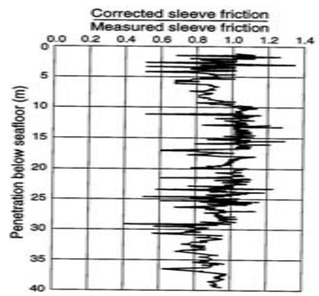


Fig 3.4

CPT/CPTU

Penetration length and penetration depth

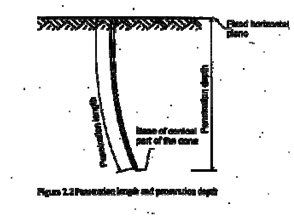


Figure 2.2 Penetration length and penetration depth

Penetration length and depth

- ***Penetration depth:*** **Depth of the base of the cone, relative to a fixed horizontal plane.**
- ***Penetration length*****: Sum of the length of the push rods and the cone penetrometer, reduced by the height of the conical part, relative to a fixed horizontal plane.**
- **Note: The fixed horizontal plane usually corresponds with a horizontal plane through the (underwater) ground surface at the location of the test.**

Correction of penetration depth according to IRTP (1999)

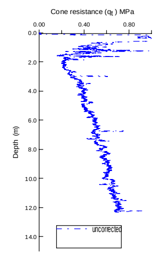
$$z = \int_0^l C_h \cdot dl$$

z = penetration depth, in m;
l = penetration length, in m;
C_h = correction factor for the effect of the inclination of the cone penetrometer relative to the vertical axis

For single axis inclinometer : $C_h = \cos\alpha$
α is the measured angle relative to vertical axis

For bi-axial inclinometer: $C_h = (1 + \tan^2\alpha + \tan^2\beta)^{-1/2}$
α and β are the angles relative to vertical axis and perpendicular to each other
For Accuracy Classes 1, 2 and 3

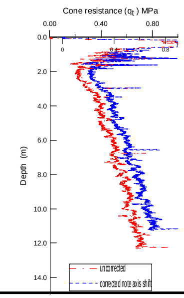
Effects of inclination, coiled rod system

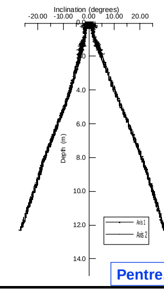


Pentre,UK

Powell,2001

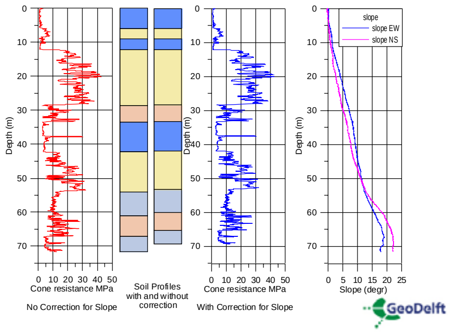
Effects of inclination, coiled rod system





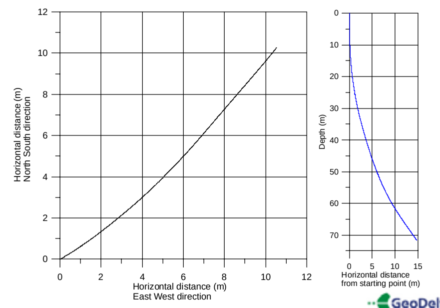
Pentre, UK

Example of depth correction



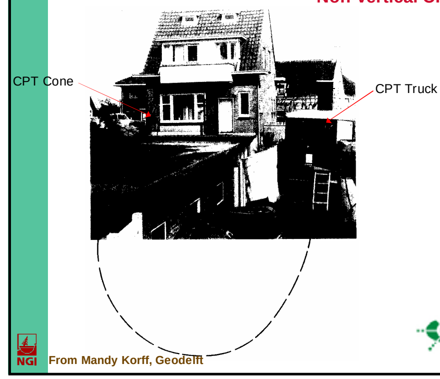
From Mandy Korff, Geodelft

Example of effect of inclined test



From Mandy Korff, Geodelft

Non-vertical CPT



From Mandy Korff, Geodelft

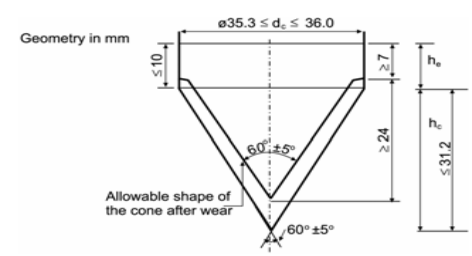
Main elements of new Eurocode on CPT/CPTU ISO/FDIS 22476-(E).13

- Equipment
- Procedures
- Corrections
- Other aspects
- Maintenance, calibration, requirements to accuracy, pore pressure response, wear, tolerances in dimensions,need for documentation when deviating from requirements, etc

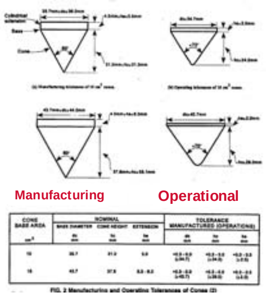
Effect of Wear

- If the allowable tolerances of the IRTP for cone diameter are adhered to, then the maximum error in q_c that can be obtained by assuming a 10 cm^2 cross sectional area of the cone is 5%, simply from wear of the cone diameter.
- These errors can be significantly greater if regular checks are not made for wear of the cone and friction sleeve.

Cone geometry IRTP tolerances



ASTM D 5778 (1995/2000)

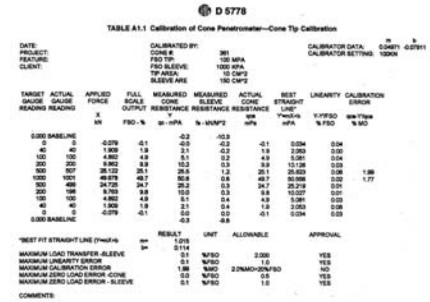


Some comments about ASTM D5778 - 95

- Detailed descriptions/instructions on large number of matters : filter types and fluids,friction reducers,calibration of new and repaired cone penetrometers. Includes allowance for 15 cm^2 cone area.
- Does not give any requirements to total accuracy of measurements. For new manufactured or repaired penetrometers the following requirements are given:
  - *linearity better than 1 % of FSO (full scale output)*
  - *zero load better than +- 14 kPa (1.0 lb/in^2)*

  SI units

ASTM D 5778 (1995)



D 5778

TABLE A1.1 Calibration of Cone Penetrometer—Cone Tip Calibration

DATE:
PROJECT:
FEATURE:
CLIENT:

CALIBRATED BY:
CONE #: 361
FSO TIP: 100 MPA
FSO SLEEVE: 1000 KPA
TIP AREA: 10 CM^2
SLEEVE ARE: 150 CM^2

CALIBRATOR DATA: m 0.04971 b -0.07911
CALIBRATOR SETTING: 100KN

TARGET GAUGE READING	ACTUAL GAUGE READING	APPLIED FORCE X kN	FULL SCALE OUTPUT FSO - %	MEASURED CONE RESISTANCE Y qc - mPA	MEASURED SLEEVE RESISTANCE fs - kN/M^2	ACTUAL CONE RESISTANCE qca mPa	BEST STRAIGHT LINE* Y'=mX+b mPA	LINEARITY Y-Y'/FSO % FSO	CALIBRATION ERROR qca-Y/qca % MO
0.000 BASELINE				-0.2	-10.3				
0	0	-0.079	-0.1	-0.0	-0.2	-0.1	0.034	0.04	
40	40	1.909	1.9	2.1	-0.2	1.9	2.053	0.00	
100	100	4.882	4.9	5.1	0.2	4.9	5.081	0.04	
200	200	9.862	9.9	10.2	0.3	9.9	10.128	0.03	
500	507	25.122	25.1	25.5	1.2	25.1	25.833	0.08	1.99
1000	1001	49.679	49.7	50.8	0.8	49.7	50.888	0.02	1.77
500	499	24.725	24.7	25.2	0.3	24.7	25.219	0.01	
200	198	9.763	9.8	10.0	0.3	9.8	10.027	0.01	
100	100	4.882	4.9	5.1	0.4	4.9	5.081	0.03	
40	40	1.909	1.9	2.1	0.4	1.9	2.053	0.08	
0	0	-0.079	-0.1	0.0	0.0	-0.1	0.034	0.03	
0.000 BASELINE				-0.3	-9.8				

		RESULT	UNIT	ALLOWABLE	APPROVAL
*BEST FIT STRAIGHT LINE (Y=mX+b)	m=	1.015			
	b=	0.114			
MAXIMUM LOAD TRANSFER -SLEEVE		0.1	%FSO	2.000	YES
MAXIMUM LINEARITY ERROR		0.1	%FSO	1.0	YES
MAXIMUM CALIBRATION ERROR		1.99	%MO	2.0%MO>20%FSO	NO
MAXIMUM ZERO LOAD ERROR -CONE		0.0	%FSO	0.5	YES
MAXIMUM ZERO LOAD ERROR - SLEEVE		0.1	%FSO	1.0	YES

COMMENTS:

Important element of new Eurocode on CPT/CPTU prEN 22476-1.10

<u>Introduction of Application Classes</u>

- Main purpose is to allow for differences in
  - *Soil conditions*
  - *Project requirements*
  - *Use of results*
    - Stratigraphy only
    - Engineering parameters
  - *National/ regional traditions and experience*

- Should lead to more comparable tenders
- Need to educate all parties involved:
  - *Clients*
  - *Contractors*
  - *Consultants*
  - *Others*

Table 1 — Application Classes

New European standard

Application Class	Measured parameter	Allowable minimum accuracy [a]	Maximum length between measurements	Use: Soil type [b]	Use: Interpretation [c]
1	Cone resistance Sleeve friction Pore pressure Inclination Penetration length	35 kPa or 5 % 5 kPa or 10 % 10kPa or 2 % 2° 0,1 m or 1%	20 mm	A	G, H
2	Cone resistance Sleeve friction Pore pressure Inclination Penetration length	100 kPa or 5 % 15 kPa or 15 % 25 kPa or 3 % 2° 0,1 m or 1 %	20 mm	A B C D	G, H* G, H G, H G, H
3	Cone resistance Sleeve friction Pore pressure Inclination Penetration length	200 kPa or 5 % 25 kPa or 15 % 50 kPa or 5 % 5° 0,2 m or 2 %	50 mm	A B C D	G G, H* G, H G, H
4	Cone resistance Sleeve friction Penetration length	500 kPa or 5 % 50 kPa or 20 % 0,2 m or 1 %	50 mm	A B C	G* G* G*

Notes : a. Allowable min. accuracy is larger of values

b. A : Uniform very soft to stiff calyes and silts D : Very stiff to hard soils q_c > 4 MPa

c. G : profiling and identification H : interpretation in terms of engineering parameters
G*/H* : Indicative

PRESENTATION of RESULTS

The information that should be presented falls naturally into the following 3 categories:

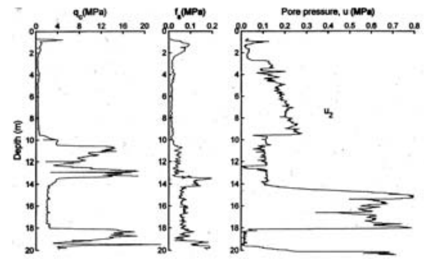
- *Measured parameters*
- *Corrected and derived parameters*
- *Additional information*

CPT/CPTU data processing and presentation of results

- Measured Parameters
  - *Cone resistance vs depth* — q_c - z
  - *Sleeve friction vs depth* — f_s - z
  - *Penetration pore pressure vs depth* — u_2 - z
  - *Other pore pressures vs depth* — u - z
  - *Pore pressure dissipation vs time* — u - t
  - *Inclination*

NGI

Examples measured CPTU parameters



Example: Measured CPTU Parameters

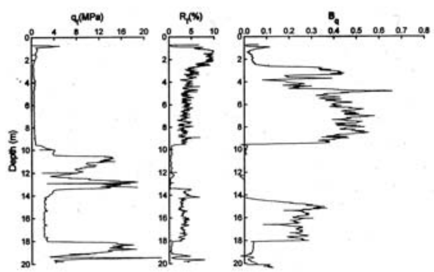
NGI

CPTU/CPTU New IRTP - presentation

- Derived parameters
  - *Excess pore pressure* — $\Delta u = u_t - u_0$
  - *Corrected cone resistance* — $q_t = q_c + (1 - a)u_2$
  - *Net cone resistance* — $q_n = q_t - \sigma_{vo}$
  - *Friction ratio* — $R_f = (f_s/q_c) \,.\, 100\%$
  - *Pore pressure ratio* — $B_q = (u_2 - u_0)/q_t - \sigma_{vo})$
  - *Normalised excess pore pressure* — $U = (u_t - u_o)/(u_i - u_o)$

NGI

Example derived CPTU parameters



Example: Derived CPTU Parameters

NGI

Additional information

Information that must be provided
Each diagram with CPT or CPTU results shall include the following information:

- Site name
- Test No.
- Date of performing test
- Serial No. of cone penetrometer
- Position of porous element(s)
- Ground water level (or water depth)
- Name and signature of the operator and the company
- Depth of predrilling if relevant

NGI

Additional information

- Observed wear or damage on cone, friction sleeve or filter element.
- Any irregularities during testing relative to ISSMGE Reference Procedure or other standard being used.
- Area ratio of cone 'a' and the friction sleeve end areas.
- For dissipation tests it should be noted whether or not the rods were clamped or unclamped during dissipation

NGI

Use of CPT/CPTU in Geotechnical Soil Investigations

Summary

- Equipment and procedures standardised
- Tests can be carried out onshore and offshore to large depth
- Reliable results can be obtained

NGI

Reliability of CPTU results

Best approach to obtain accurate and representative CPTU results is to follow :

New Eurocode on CPT/CPTU
ISO/FDIS 22476-(E).13

or before this is finalized :

International Reference Test Procedure
(ISSMGE, 1999)

- **Published in Proc. ECSMFE, Amsterdam,1999**

NGI

Use of CPT/CPTU in Geotechnical Soil Investigations

Spare overheads

NGI

CHECKS, CORRECTIONS AND PRESENTATION OF DATA

- **Factors affecting measurements and corrections**
  - ***Pore water pressure effects on q_c and f_s***
  - ***Filter location***
- **Effect of axial load on pore water pressure readings**
- **Temperature effects**
- **Inclination**
- **Calibration and Resolution of sensors**
- **Effect of wear**
- **Correction for CPTU zeroed at the base of a borehole (offshore)**

NGI

CHECKS ON DATA QUALITY

- **A rough check to see if the measured q_c are within the following acceptable lower limits is:**

  $q_c > \sigma_{vo}$ $(= \gamma_{av} \cdot z)$

  where γ_{av} is the average unit weight of soil and z is depth below ground level.

Setting γ_{av} equal to 15 kN/m^3 the check becomes:

$q_c > 15z$ **in kPa**

NGI

CHECKS ON DATA QUALITY

Before using the data for interpretation in terms of soil parameters for design it is advisable to make the following checks:

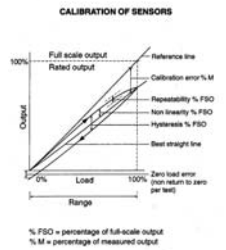
- **Check if the difference in zero readings before and after a test are within acceptable limits (in soft clays this may correspond to ± 20 kPa for qc). If the difference in zero readings is significant then the CPT results should be corrected or discarded.**
- **If inclination of the cone penetrometer is measured during a test this should be reviewed; for deep tests a significant inclination will tend to give false depth readings.**

NGI

Zero reading, reference reading and zero drift

- *Zero reading*: The output of a measuring system when there is zero load on the sensor, i.e. the measured parameter has a value of zero, any auxiliary power supply required to operate the measuring system being switched on.
- *Reference reading*: the reading of a sensor just before the penetrometer is pushed into the soil e.g. in the offshore case the reading taken at the sea bottom - water pressure acting.
- *Zero drift*: Absolute difference of the zero reading or reference reading of a measuring system between the start and completion of the cone penetration test.

Definition of calibration characteristics



From Schaap and Zuidberg(1982)

Fig 2.17

CHECKS, CORRECTIONS AND PRESENTATION OF DATA

The purpose is to ensure that data obtained from a CPT/CPTU are of a known quality and presented in a clear and systematic way.

Three important aspects:

- factors that might affect the measurements and how to avoid or correct for them,
- the presentation of data to ensure that they are of most use
- a quick summary guide to information required to enable checking of the data quality.

CPT/CPTU: Sources of error

- Pore pressure effect on cone resistance and sleeve friction
- Zero shift including temperature effects
- Pore pressure measurement system not saturated
- Large inclination of cone penetrometer
- Cross talk between cone and friction sleeve
- Reduced area of cone due to wear
- Zeroing location
- Friction reducers too close to cone penetrometer
- Electrical faults
- Malfunctioning depth measurements